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Assessing Spatial Dynamics of Cougars (*Puma concolor*) in North-central Montana:

Distribution, Resource Selection, Dynamics, Harvest Opportunities, and Conservation Design

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1. Background

Increasing attention is being directed to ecological restoration in North American grasslands (Forrest et al. 2004), particularly with respect to species that have been lost or eliminated from these systems. Some species, notably wolf (*Canis lupus*), bear (*Ursus* spp.), and cougar are expanding in Montana through reintroductions and natural recolonization. While the value of large carnivores to ecosystem function is increasingly understood (Terborgh et al. 1999; Pyare and Berger 2003; Smith et al. 2003; Soule et al. 2003, Licht et al. 2010), large carnivores present major challenges and opportunities for communities, ranchers, and wildlife managers, because they may also kill livestock or reduce big game population numbers in landscapes where they have been absent in recent history. Because large carnivores operate at multiple but often large scales, management, conservation, and restoration of top carnivores have played a significant role in fostering ecosystem approaches to wildlife management (Minta et al. 1999).

Cougars have expanded into much of central and eastern Montana as well as northeastern Montana and North Dakota. Much of the landscape in north-central Montana appears suitable for expansion by cougar. Prey populations are robust and there are large contiguous blocks of undeveloped land. The area contains the largest block of protected and public lands in the Great Plains (e.g. Charles M. Russell National Wildlife Refuge (CMR) and adjacent Upper Missouri River Breaks National Monument (UMRBNM), as well as several million acres of Bureau of Land Management lands) and a diverse mix of potentially suitable habitats. It is important to understand and document how cougars are using the landscape as they recolonize it, because it will provide much insight into conservation strategies for this species, its prey and what might occur as other carnivores expand into the region (Mladenoff et al. 1999).

Information about cougar recolonization and ecology of established populations will greatly enhance understanding and management of cougars in the grasslands and prairie breaks of north-central Montana. This is especially important because cougars have been little studied in this type of landscape (Williams 1992) and very little work has been conducted anywhere on a recolonizing cougar population. Montana Fish, Wildlife, and Parks (FWP, 1996) has adopted a cougar management program (including harvest) that uses regional management based on habitat capabilities of respective regions, and the CMR is developing harvest management guidelines as part of its ongoing planning processes. But because very little is known about capabilities of landscapes in this region to support cougars, nor about the factors affecting habitat use or current population levels (Pierce et al. 2000, Grigionne et al 2002), or how to design and manage Refuge populations to ensure persistence of cougars and other large carnivores (Woodruff and Ginsberg 2000, Carroll et al. 2002), additional information on cougar ecology, threats, and habitat use is needed.

First, data are needed to understand if and how the cougar population in north-central Montana is expanding, if it will be viable over the long term in this region, and what management is required to ensure it remains viable. To provide appropriate management, we need to determine if and how this population is connected to other cougar populations (Beier 1996; Sweanor et al. 2000; Laundre and Clark 2003), to other source populations, where the sources and sinks are (Doak 1995; Sweanor et al. 2000) and how we ensure it remains a functional part of the larger statewide cougar metapopulation (Haight et al. 1998). Addressing these questions will also provide information about connectivity in the region for other species and can add significant information about management needs to ensure this connectivity potential remains intact (Boyd and Pletscher 1999; Craighead et al. 1999).

Second, as wildlife managers move to more sophisticated models of cougar harvest as opposed to general seasons (unlimited harvest of either sex), they will need to have information on which to base harvest levels. Limited entry (harvest is limited by restricting the number of licenses sold), quota system (harvest is limited by season closure once a prescribed number of animals are taken) and "zone management" (Logan and Sweanor 2001) or "metapopulation" model (Laundre and Clark 2003) strategies are thought to reduce the risk of overharvest by ensuring a sustainable loss of the total population (limited entry), reduction of female mortality (quota system), or preservation of source populations that sustain hunted areas (metapopulation model).

Developing information about how cougars select habitats, as well as spatial information will provide a better understanding of what habitats are supporting cougars in grassland ecosystems as well as some estimate of the population size and structure. At the very least, more information on factors affecting sustainability of harvest in general based on regional conditions would be useful, particularly in regions with lower cougar densities and connectivity, and would be a very valuable contribution in designing a zone management system for Montana.

Finally, as with other carnivores, recolonizing cougars may have an important effect on ungulate populations (Kunkel et al. 1999). Logan and Sweanor (2001), for example, reported predation by cougars on mule deer (*Odocoileus hemionus*) was partly additive and was the primary limiting factor for mule deer. Recent work in west-central Montana and in central Idaho indicate cougars are a primary factor affecting elk (*Cervus elaphus*) calf recruitment (D. Pletscher, University of Montana, personal communication; P. Zager, Idaho Fish and Game, unpublished data). Bighorn sheep (*Ovis canadensis*) may be significantly impacted in local areas by cougars (Kunkel et al. 2007), and once population declines start they are difficult to reverse (Wehausen 1999; Kamler et al 2002; Rominger et al 2004). Additionally, cougars may cause prey to shift habitat use and thereby affect responses in ecological communities (Atwood et al. 2007, Atwood et al 2010). Predation by large carnivores including cougars may shape ecosystems through top down effects (Ripple and Breschta 2007) that are important to ecosystem functions. These impacts vary by abundance and species of carnivores present, a dynamic and important process to understand for management and conservation (Dalerum et al 2008, Licht et al. 2010).

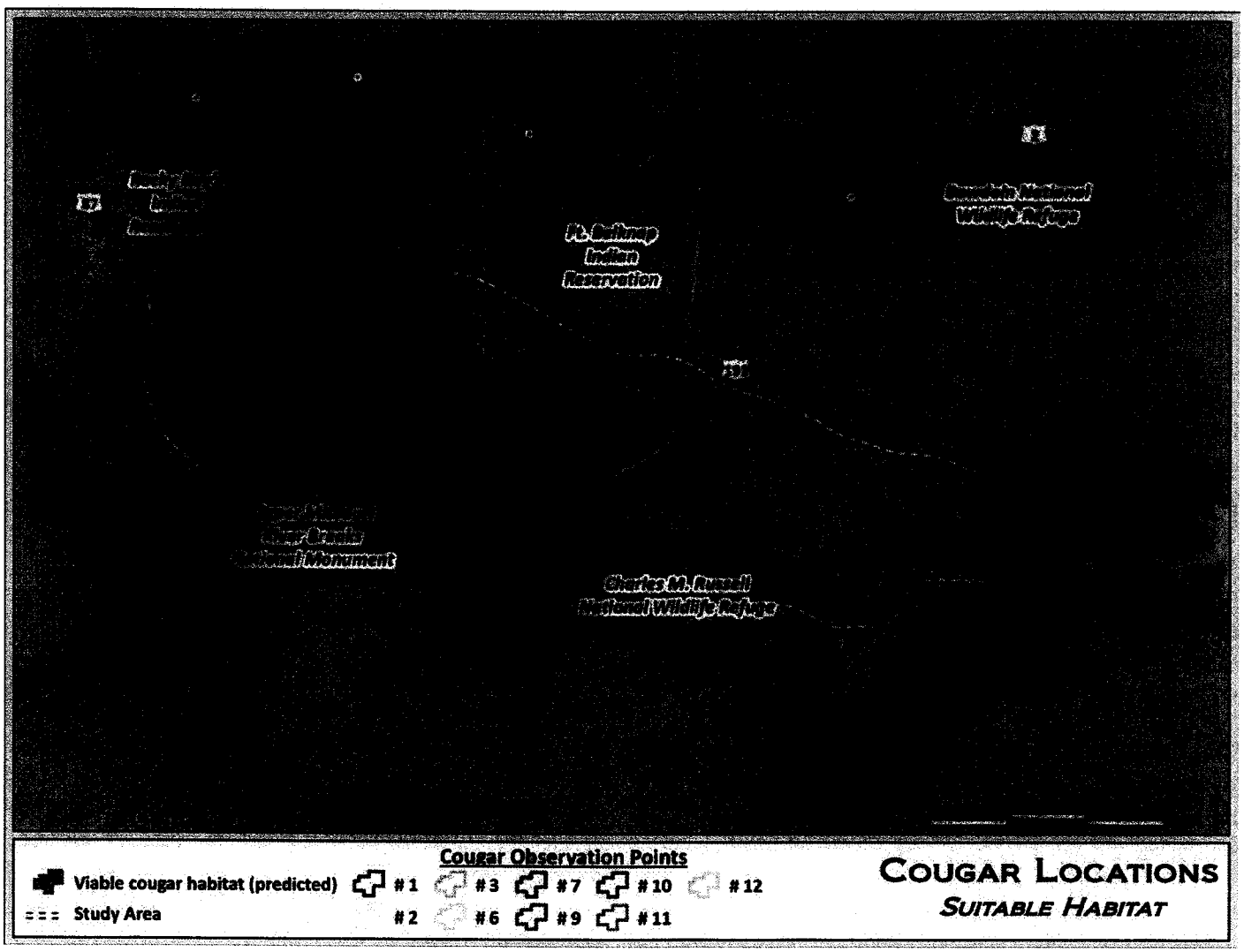


Figure 1. Home range minimum convex polygons for GPS-collared cougars on and around Rocky Boy's and Ft. Belknap Indian Reservations overlayed on cougar habitat suitability index developed by Riley and Malecki (2001).

2. Project Goals & Objectives

Overall Goal

Understand cougar population dynamics, habitat use, and distribution to assess needs for large carnivore conservation in a prairie landscape in a multi-jurisdictional setting.

Objectives

1. Obtain a minimum count estimate of cougars within the project area and factors influencing this, including prey base, harvest levels, and landscape components and configuration;

2. Obtain estimated rate of cougar mortality, as well as cougar density, population distribution, and reproduction;

3. Obtain estimates of size and composition of cougar home ranges and habitat use patterns;

4. Determine the role of the Little Rockies and Bears Paws as a potential source population and factors influencing this including connectivity between these sky island mountain ranges which are largely contained within the Ft. Belknap (FB) Indian Reservation and Rocky Boy's (RB) Indian Reservations (respectively) and the Missouri River Breaks and other nearby habitats (dispersal);

5. Obtain estimates of overlap and potential for conflicts between cougars and livestock and prescriptions to reduce conflicts.

3. Study Area

The Rocky Boy's and Ft. Belknap Indian Reservations are located in north central Montana (Figure 1). The reservations include a variety of terrain ranging from 1,000 – 2,300 m including the Bears Paw Mountains, Little Rockies Mountains, foothills, mixed-grass prairie, coniferous and mixed-coniferous/deciduous forests, and wetlands. The project area encompasses approximately 7,000 km^2.

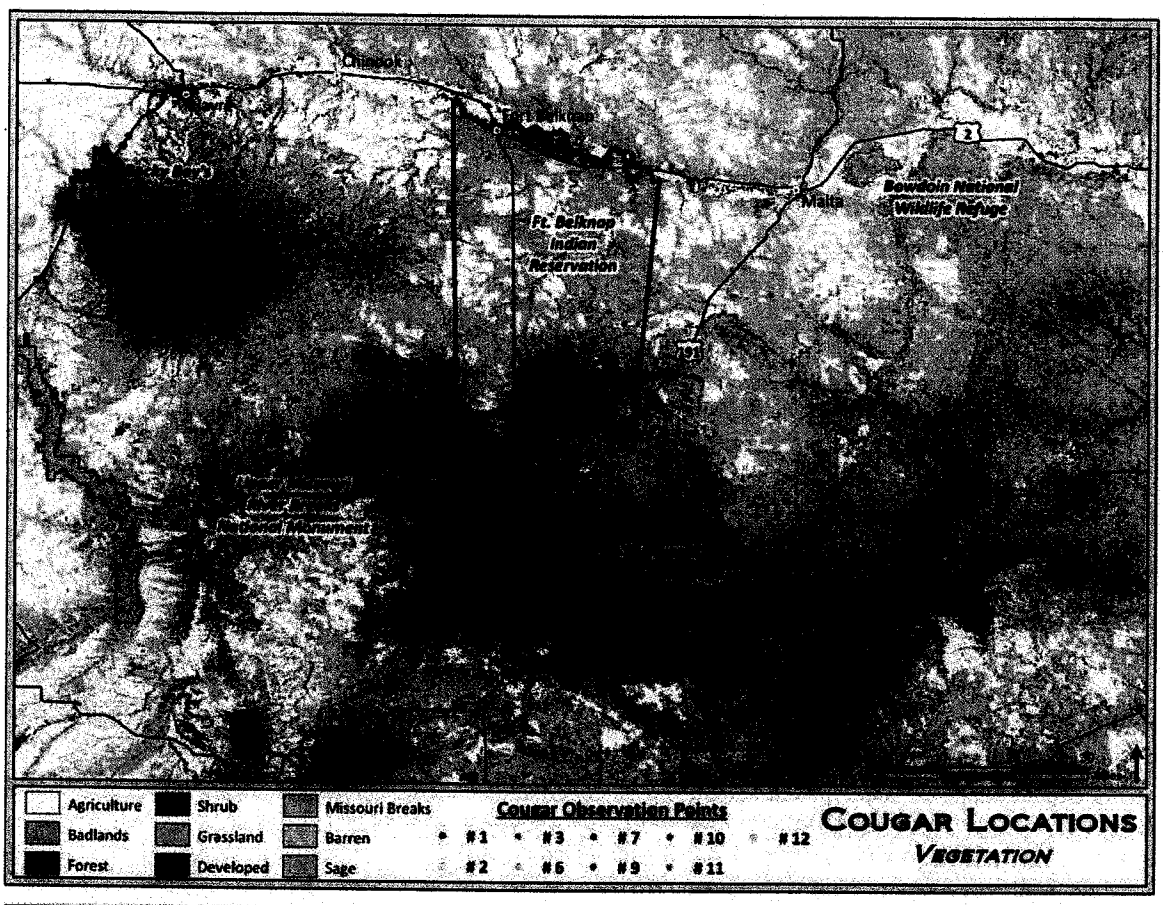
The Bears Paws and Little Rockies are large volcanic mountains chains, sky islands in the eastern Montana prairie and been rated as "high" for biodiversity (TNC 1999). We know of no wildlife research ever conducted in either of these ranges. Rocky Boy's has reintroduced bighorn sheep to the Bears Paws.

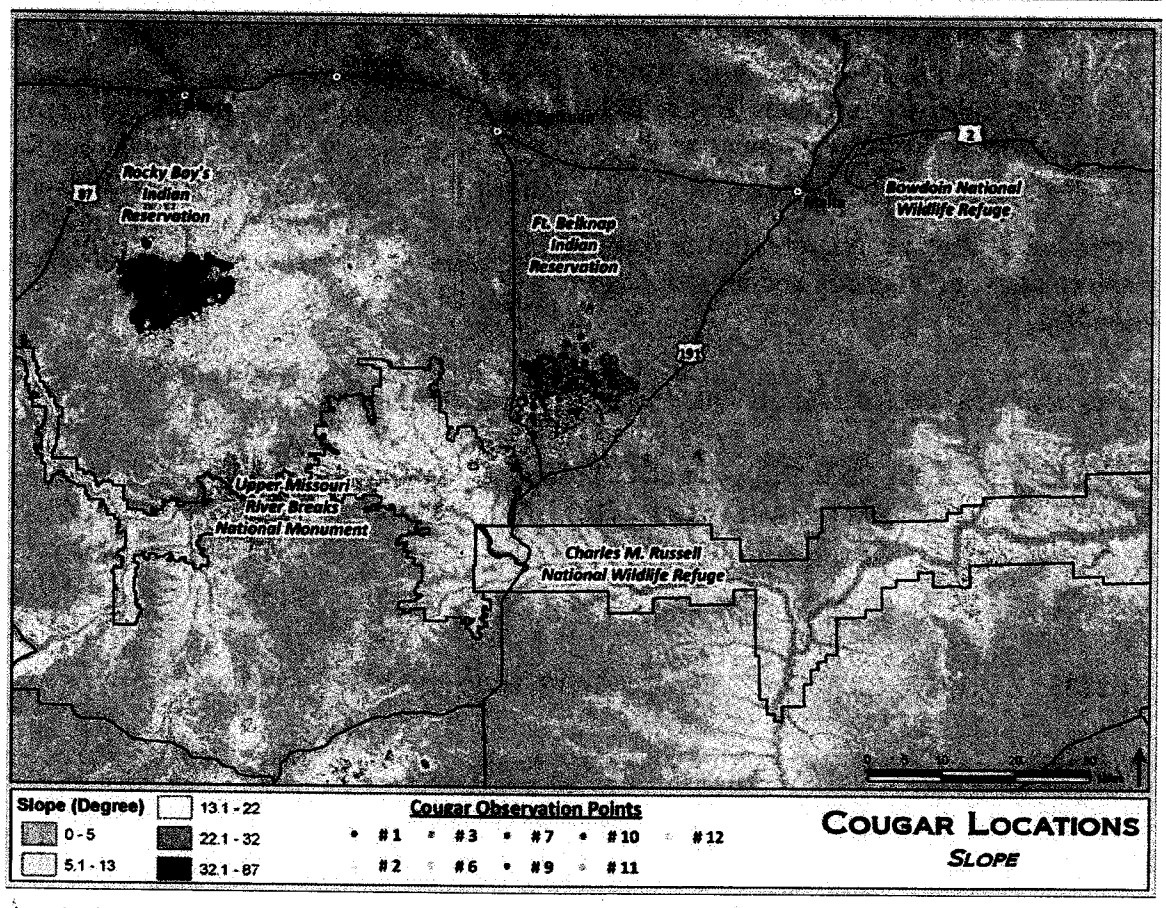
The area outside the mountains is characterized by level to rolling plains in the north trending to deeply dissected and rugged topography near the Missouri River in the south. Western wheatgrass (*Agropyron smithii*) grasslands and big sage (*Artemesia tridentada*) shrublands dominate the level to rolling plains. Greasewood (*Sarcobatus vermiculatus*) shrublands are located on soils with concentrated salts in uplands and in claypans. Breaks along the Missouri are dominated by bluebunch wheatgrass (*Agropyron spicatum*) grasslands and low elevation coniferous forest/woodlands. Prey species for cougars include white-tailed deer, mule deer, bighorn sheep, elk and beaver (*Castor canadensis*) at relatively high but varying densities across the region.

Table 1. Date, ID, location and status of cougars collared, winter 2006/2007 and 2007/2008.

Date collared	Cougar #	Age/Sex	Location	Status
12/2006	1	Adult Male	Sandy Creek, Bears Paws	Harvested, 2/2007*
12/7/2007	2	Adult Male	Eagle Creek, Bears Paws	Harvested, 1/2009*
12/12/2007	3	Adult Female	Lost Canyon, Bears Paws	Probable harvest 12/2008
1/25/2008	4	Subadult Female	Beaver Creek, Little Rockies	Missing
2/1/2008	5	Adult Male	Bailey Mtn., Bears Paws	Harvested 2/2009
2/14/2008	6	Adult Male	Bear Gulch, Little Rockies	Recollared 10/23/08*
3/31/2008	7	Adult Female	Baldy Mountain, Bears Paws	Natural Mortality 7/2008*

**collar retrieved and downloaded*





Figures 2 (Top) and 3 (Bottom). Cougar GPS locations overlayed on important landscape attributes, vegetation and slope, to visually evaluate how cougar distribution patterns are influenced by the landscape.

4. Methods

We used GPS radio collars to determine cougar mortality and movements (Beier 1995, Kunkel 1997, Kunkel et al. 1999, Sweanor et al. 2000, Anderson and Lindzey 2003). We either captured cougars using hounds released on tracks or snares (Kunkel et al 2007). We immobilized captured cougars and then fitted them with a radio collar. We located cougars via aerial telemetry to detect mortality and dispersing or wide-ranging animals at least monthly. Collars were equipped with mortality sensing devices in order to measure cougar mortality rates and causes and factors influencing mortality. We recorded hunter harvested animals. We considered intraspecific strife to be the cause of death when blood, subcutaneous hemorrhaging at wound sites, or signs of a struggle were found at the site. We computed survival and cause-specific mortality rates via the program MICROMORT (Heisey 1985, Heisey and Fuller 1985). We compared daily survival rates for each interval by examining overlap among confidence intervals, pooling data from intervals if rates were not significantly different (Heisey and Fuller 1985). We assumed that signal loss from radio collars after the expected 2-year life of the battery had resulted from battery failure. We recorded number of kittens we located with females.

GIS Mapping

We uploaded GPS locations for each cougar into point shapefiles in ArcMap 9.3 (ESRI 2008). We error checked data and removed invalid points (e.g., those recorded after an animal was harvested). We used the remaining points to create a home range minimum convex polygon using the Hawth's Tools Animal Movement extension (Beyer 2004). We created polygons that were overlayed on previously developed models of suitable cougar habitat (Riley and Malecki 2001, Figure 1) and important landscape attributes (i.e., vegetation, slope; Figures 2 and 3) to visually evaluate how cougar distribution patterns are influenced by the landscape.

5. Annual Summary

Winters 2006/2007 and 2007/2008

We spent 30 days in the field searching for cougar tracks and caught 7 cougars. We collared 5 cougars on Rocky Boy's and 2 on Ft. Belknap (Table 1). Four of these cougars were harvested and 1 was "probably harvested" based on the data from a cougar we collared (#3, Table 1) that showed she had an established home range that overlapped the location where an adult female was harvested on the RB reservation in December 2008. This female had 3 kittens with her when she was captured and collared. Harvest of male cougar #5 was verified from blood samples we obtained from this individual that allowed us to match DNA from an individual harvested in the Bears Paws (Table 1).

Table 2. Date, ID, location and status of cougars collared during 2008/2009.

Date collared	Cougar #	Age/Sex	Location	Status
10/23/2008	6	Adult Male	Lodgepole Creek, Little Rockies	Harvested 1/2009*
12/17/2008	8	Subadult Male	Lower Sandy Creek, Bears Paws	Harvested 12/8/09
2/3/2009	9	Adult Male	Beaver Creek, Bears Paws	Harvested 3/11/09*
3/31/2009	10	Adult Female	Browns Canyon, Little Rockies	Natural Mortality 12/2009*
4/2/2009	11	Adult Female	Big Warm, Little Rockies	Harvested 10/2009*
5/31/2009	12	Subadult Male	Beaver Creek, Bears Paws	Recollared 10/30/09*

**collar retrieved and downloaded*
Note: Male cougar # 6 was recollared on October 23, 2008 on the Fort Belknap Indian Reservation.

Table 3. Date, age, sex and location of cougars harvested by hunters in FWP Region 6 during 2008/2009 season.

Date of Harvest	Age	Sex	Collared cougar #	Location of Kill
December 2008	Adult	Female	3	Sandy Creek, Rocky Boy's
December 2008	Subadult	Male		Sandy Creek, Rocky Boy's
December 2008	Adult	Male		Eagle Creek, Rocky Boy's
January 2009*	Adult	Male	6	Thornhill, Butte BLM
January 2009	Subadult	Male		Eagle Creek, Private
January 2009	Adult	Male	2	Eagle Creek, Private
February 2009	Adult	Male	5**	Eagle Creek, Private
March 2009	Adult	Male	9	Eagle Creek, Private
March 2009	Adult	Male		Eagle Creek, Private
April 2009	Adult	Male		Baldy Mtn., Private

Note: Another collared male (#1) was harvested on private land in Eagle Creek in February 2007.
** Harvest date was either December 2008 or January 2009.*
*** see Table 1.*

Winter 2008/2009

We spent 27 days in the field searching for cougar tracks, 23 days on Rocky Boy's and 4 days on Ft. Belknap, and snared for 190 trap nights during summer and fall 2009. We caught 9 cougars, including 3 kittens, and collared 2 of the adults on Rocky Boy's (one by foot snare - #12) and 3 (one by foot snare (#13; Table 2) on Ft. Belknap. We captured # 12 in a foot snare in May 2009 on Rocky Boy's.

Hunters killed 9 cougars in the Bears Paws during the 2008/2009 hunting season (Table 3). Eight of the 9 cougars killed were males (6 adults, 2 subadults). Five adult males and 1 subadult males were killed off of the reservation. Three cougars were harvested on the Rocky Boy's including an adult male, an adult female, and a subadult male (Table 3). Another adult male (# 6) was harvested on public land near the Little Rockies and another cougar was killed in a trap in the Missouri Breaks.

Winter 2009/2010

We spent 29 days in the field searching for cougar tracks, 18 days on Rocky Boy's and 10 days on Ft. Belknap. We captured and recollared #12 in October 2009 on Rocky Boy's (Table 4). This male was harvested adjacent to the Rocky Boy's in December 2009

A minimum of 9 cougars were harvested in the Little Rockies (Table 5). Four females and 1 male cougar were harvested on Ft. Belknap and 1 female and 2 males were harvested on public land in the Little Rockies during the fall and winter 2009/2010. Another adult female was killed near the reservation boundary in December 2009.

A hunter harvested #8 on the Ft. Belknap in December 2009. This young male dispersed from the Rocky Boy's where he was collared the previous winter. We retrieved the collars from female #10 and #11. Cougar #10 died of natural causes. We are currently monitoring #13 and #14.

6. Overall Summary

Harvest and Mortality

We have collared 6 females and 8 males. Three males and 1 female were subadults. Of the 13 cougars for which we have data on ultimate fate, (including #3 probable harvest and censoring #4 whose fate is unknown), hunters harvested 9 and 2 died of natural causes, and 2 are still presumed alive. During the period of December 2006 (1st capture) through May 2010 the overall survival rate was 0.01 (Table 6). Hunter harvest mortality rate for that period was

Table 4. Date, ID, location and status of cougars collared during 2009/2010.

Date collared	Cougar #	Sex	Location	Status
10/4/2009	13	Adult Female	Bear Gulch, Little Rockies	Monitoring
10/30/2009	12	Adult Male	Lost Canyon, Bears Paws	Harvested 12/2009*
5/8/2010	14	Subadult Male	Green Creek, Bears Paws	Collar dropped* 7/10/10

**collar retrieved and downloaded*

0.81. Sample sizes for testing rate differences among years and between sexes were too small (Table 6). Mean number of months alive post capture for cougars was 8 (range = 1-12).

At the beginning of 2008/2009 hunting season we only knew of 1 adult male (# 2) and 1 subadult (# 8) on Rocky Boy's. We did not capture or find any adult male cougar tracks after January 2009 and we caught a subadult male cougar (#12) in May 2009 (harvested 12/09).

At the beginning of 2009/2010 hunting season we only knew of 2 adult cougars in the Bears Paws, including #12. To our knowledge, cougar #12 was the only cougar harvested in the Bears Paws this winter (Table 5). We found tracks of 1 adult female with kittens in early January 2010. We captured the juveniles but these kittens were too small to collar. We recaptured and collared the subadult male in early May.

We estimated 10-12 adult cougars in Little Rockies before the 2009/2010 hunting season. We released dogs on cougar tracks twice on Ft. Belknap during winter 2010 but did not capture any lions. We estimated that over 50% of the adult/subadult cougar population including over 66% of adult females in the population were killed this winter in the Little Rockies.

We assume that high immigration (or possibly there were more cougars in population than we detected) likely supported the high harvest of males in 2008/2009. We estimated 2 female cougars (1 of these has 2 kittens) and no male cougars on or adjacent to Rocky Boy's and 3 females and 1-2 males in Little Rockies.

One of 12 radioed cougars (#8) dispersed. He dispersed from the Bears Paws to Ft. Belknap and was killed there.

Population Parameters

We searched 130 km^2 of the Bears Paws study area for 2 years and estimate the core habitat for cougars in the Bears Paws is about 260 km^2 yielding a density of 1.5 adult cougars/100 km^2 during periods on known high population and a density of 0.7/100 km^2 during periods on lowest known population. Density estimates for cougars in North America range from 0.32-2.2 resident adults/100 km^2 (Logan et al 2000).

Table 5. Date, age, sex and location of cougars harvested by hunters in north central Montana during. 2009/2010 season.

Date of Harvest	Age	Sex	Cougar #	Location of Kill
October 2009	Adult	Female	11	Near Hays, FBIR
November 2009	Subadult	Female		Near Hays, FBIR
December 2009	Adult	Male		Lodgepole Cr., FBIR
December 2009	Adult	Female	8	McConnel Mtn., FBIR
December 2009	Subadult	Male		Near Lodgepole, FBIR
December 2009	Subadult	Female		Near Zortman, BLM
December 2009	Subadult	Male		Near Zortman, BLM
December 2009	Adult	Female		Indian Butte, FBIR
January 2010	Adult	Male		Camp Cr., BLM

Table 6. Survival rates of cougars collared in Bears Paws and Little Rockies, north-central Montana 2006-2010.

Survival Model	Survival/Mortality Rate	95% CI
2007 all survival	0.27	0.00 – 1.00
2008 all survival	0.62	0.32 – 1.00
2009 all survival	0.11	0.02 – 0.50
Male survival 2006-2010	0.01	0.00 – 0.29
Female survival 2006-2010	0.02	0.00 – 0.91
All survival 2006-2010	0.01	0.00 – 0.16
All harvest mortality 2006-2010	0.81	0.58 – 1.00
All natural mortality 2006-2010	0.18	0.00 – 0.41

We collared 5 adult females and 2 of these had kittens. One of 2 adult females in Bears Paws had 3 kittens and one of 3 females in Little Rockies had 2 kittens. We have not yet established the fates of these kittens.

Three female home ranges (MCP) ranged from 95-326 km^2 (Figure 1). Five male home ranges ranged from 160-472 km^2. The composite home range for 8 cougar was 931 km^2.

Habitat Use

Most cougar locations were within habitats we predicted and defined as cougar habitat based on ruggedness and forest cover model of Riley and Malecki (2001; Figure 1). Some locations (about 3%), however, occurred in non-rugged grasslands (Figures 2 and 3).

We found no evidence that any of our radioed cougars had conflicts with livestock or humans despite extensive overlap with allotments where cattle were present. We observed no evidence that bighorn sheep (including radio collar sheep reintroduced to the Bears Paws) were being killed by cougars.

7. Discussion

Human harvest was the primary factor limiting cougars in the Bears Paws and Little Rockies during the study period. The harvest rates we report are higher than those reported from 2002-2006 (range = 0-2) but similar to levels from 1992-2001 (range = 3-8; MFWP unpublished data). Cougar population abundance and snow conditions allowing for harvest may be factors in this trend. Based on high rate of mortality of cougars in the Bears Paws and in the Little Rockies, we hypothesize that these ranges may be "attractive sinks" for cougars (Novoro et al 2005, Kunkel et al. 2007, Robinson et al. 2008). The pre- harvest density of cougars in the Bears Paws was relatively high. Should harvest rates remain high, we hypothesize a reduction in mean male age and a reduction in overall regional cougar density. We are uncertain where the local source population(s) of cougars are that provide immigrants into Bears Paws and Little Rockies, but hypothesize the Missouri River Breaks including the C.M. Russell National Wildlife Refuge serve as one. The low number of kittens we have found recruited preliminarily indicates that the Bears Paws and Little Rockies are not self sustaining population but rather rely on immigration.

Stoner et al. (2006) reported cougar survival rates of 0.36 in Utah following 5 years of intensive harvest. Stoner et al. (2006) reported that cougar removal ranged from 17.6–54.5% of the adult population and exceeded 40% for 4 of 5 consecutive years. Under this regime the population declined by >60%. Following 3 subsequent seasons of light harvest the population recovered to only 52.4% of its original level.

The harvest rate in Bears Paws to date is similar to a population of cougars in southern New Mexico subject to very high removal levels where management for bighorn sheep restoration was the goal (Kunkel et al 2007). The number of cougars killed there every year was >50% of the minimum number of cougars estimated to have been present. The number of days that cougars remained alive (or in the study area) after being radio collared ranged from 14 to 1,047 (x = 303.3). High immigration supported this apparent attractive sink.

We found evidence of connectivity between the Bears Paws and Little Rockies and between the Little Rockies and Missouri River Breaks. Location data from 1 cougar indicates connectivity may occur via the area designated within the Upper Missouri River Breaks National Monument, which supports predictions of our habitat model (Figure 1). We also deployed camera surveys that also indicated this connection and yielded a density of 0.48-0.73 cougars/100 km^2 in the UMRBNM (Kunkel 2006). This suggests that more work is needed to determine if source populations and movement rates among these areas can sustain local and regional harvest.

8. Next Steps

We will continue capture and collaring cougars in the Bears Paws and Little Rockies through winter 2010/2011. We will begin resource selection analysis. We are developing a collaborative study design with CMR and FWP to expand the project to CMR and begin capturing and collaring cougars there in summer 2010. That work should yield better knowledge of regional cougar population dynamics and source-sink structure of the landscape. From that we can assess population viability and develop collaborative regional conservation and management plans.

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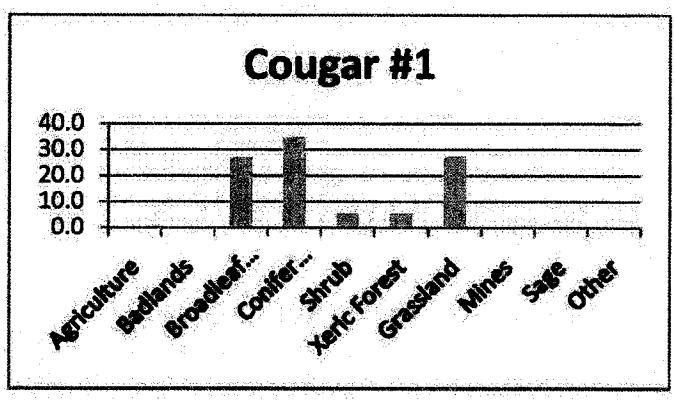
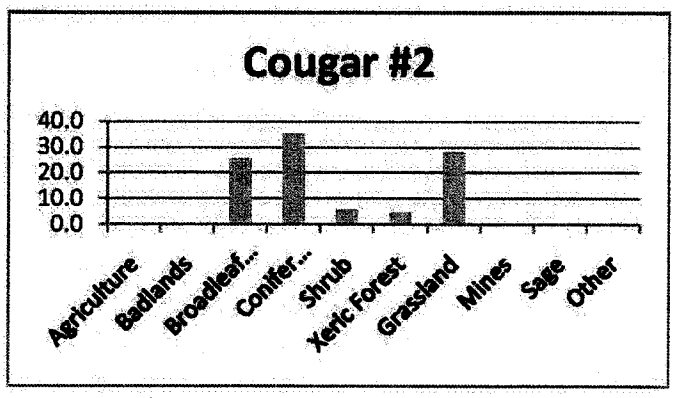
Appendix A - Cover type (vegetation class) within individual cougar home ranges

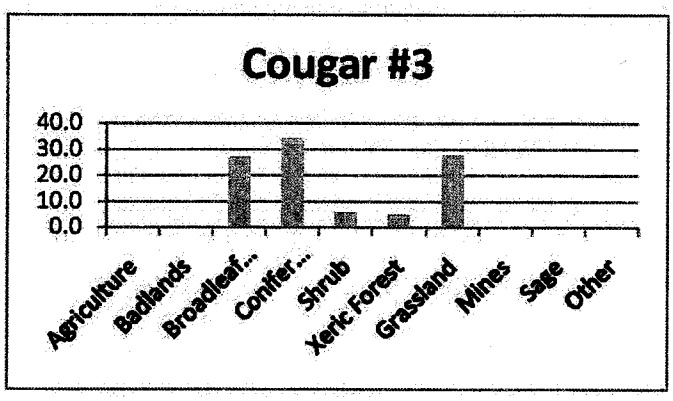
	% of vegetation type in home range
Cougar 1	
Agriculture	0.2
[redacted]	27.1
[redacted]	34.6
Shrub	5.4
Xeric Forest	5.1
Grassland	27.3
[redacted]	
Other	0.2



Cougar 2	
Agriculture	0.1
Badlands	0.0
[redacted]	25.5
[redacted]	35.1
Shrub	6.0
Xeric Forest	4.9
Grassland	28.2
[redacted]	
Other	0.1

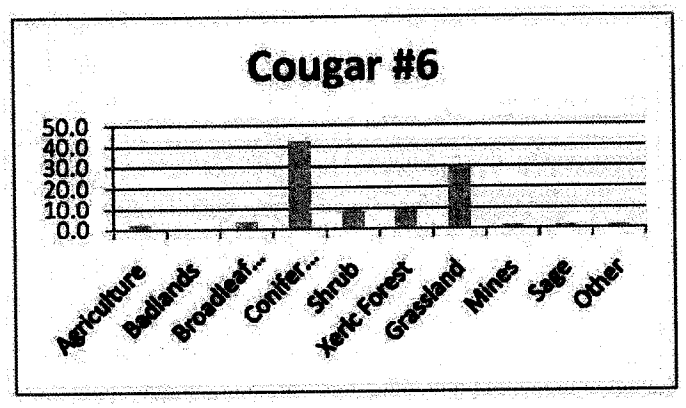


Cougar 3	
Agriculture	0.1
Badlands	0.0
Broadleaf Forest	27.2
[redacted]	34.1
Shrub	5.8
Xeric Forest	4.9
Grassland	27.8
[redacted]	
Other	0.2



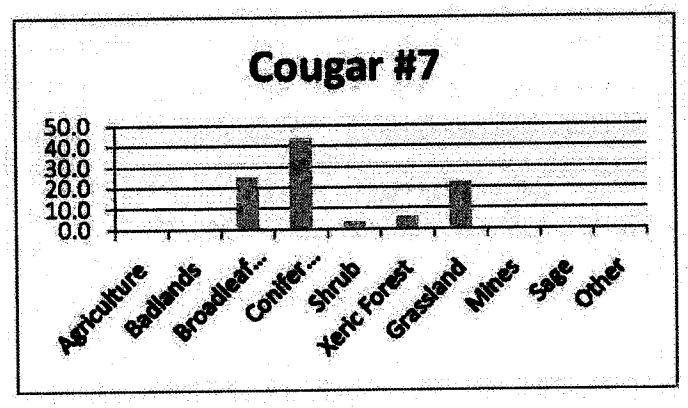
Cougar 6

Agriculture	2.1
Badlands	0.2
Broadleaf Forest	3.6
[redacted]	42.6
Shrub	8.9
Xeric Forest	8.9
Grassland	29.9
[redacted]	1.2
[redacted]	1.3
Other	1.4



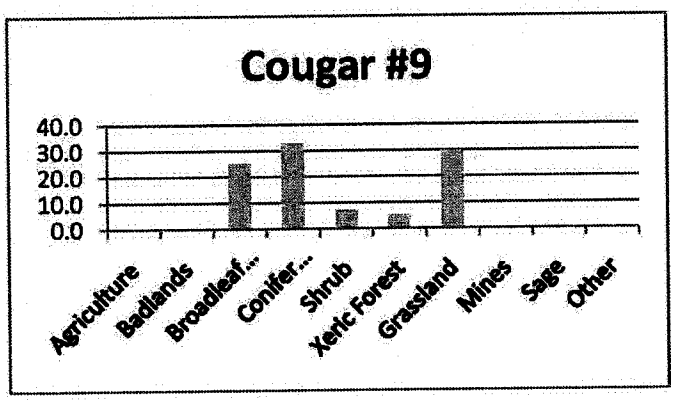
Cougar 7

Agriculture	0.2
Badlands	
[redacted]	24.9
[redacted]	43.5
Shrub	3.3
Xeric Forest	5.6
Grassland	22.1
[redacted]	
Other	0.3



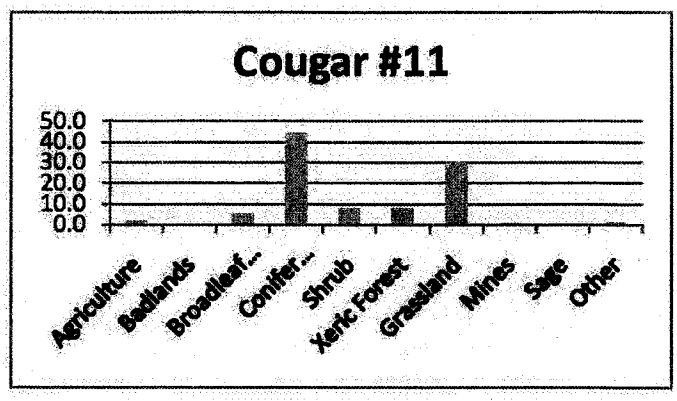
Cougar 9

Agriculture	0.1
Badlands	0.0
Broadleaf Forest	25.0
[redacted]	32.8
Shrub	7.2
Xeric Forest	5.0
Grassland	29.7
[redacted]	
Other	0.1



Cougar 11

Agriculture	1.7
Badlands	0.0
Broadleaf Forest	5.4
Conifer Forest	44.3
Shrub	7.9
Xeric Forest	8.0
Grassland	30.4
Mines	0.9
Sage	0.0
Other	1.3



Cougar 12

Agriculture	0.1
Badlands	0.0
Broadleaf Forest	27.0
Conifer Forest	41.4
Shrub	3.9
Xeric Forest	4.3
Grassland	23.0
Mines	0.0
Sage	0.0
Other	0.3